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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

27AUG02 E743701-1 C86349
P01/7700 0.00-0219818.2

Cardiff Road
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NP10 8QQ

1. Your reference — NANOPAT 3

2. Patent application number *(The Patent Office will fill in this part)* — 0219818.2 — 24 AUG 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Dr DEREK ANTHONY EASTHAM
58 Vincent Drive
CHESTER
CH4 7RL

   Patents ADP number *(if you know it)* — 840362800 1

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — FOCUSSED ELECTRON AND ION BEAMS ADDENDUM

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*
0213772.7	18-JUN-02

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* — NO
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d))

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	3
Claim *(s)*	1
Abstract	1
Drawing *(s)*	1 x1

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/~~We~~ request the grant of a patent on the basis of this application.

Signature D A Eastham Date ~~12~~ 22 August/02

12. Name and daytime telephone number of person to contact in the United Kingdom D A EASTHAM 01925-603581

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Notes

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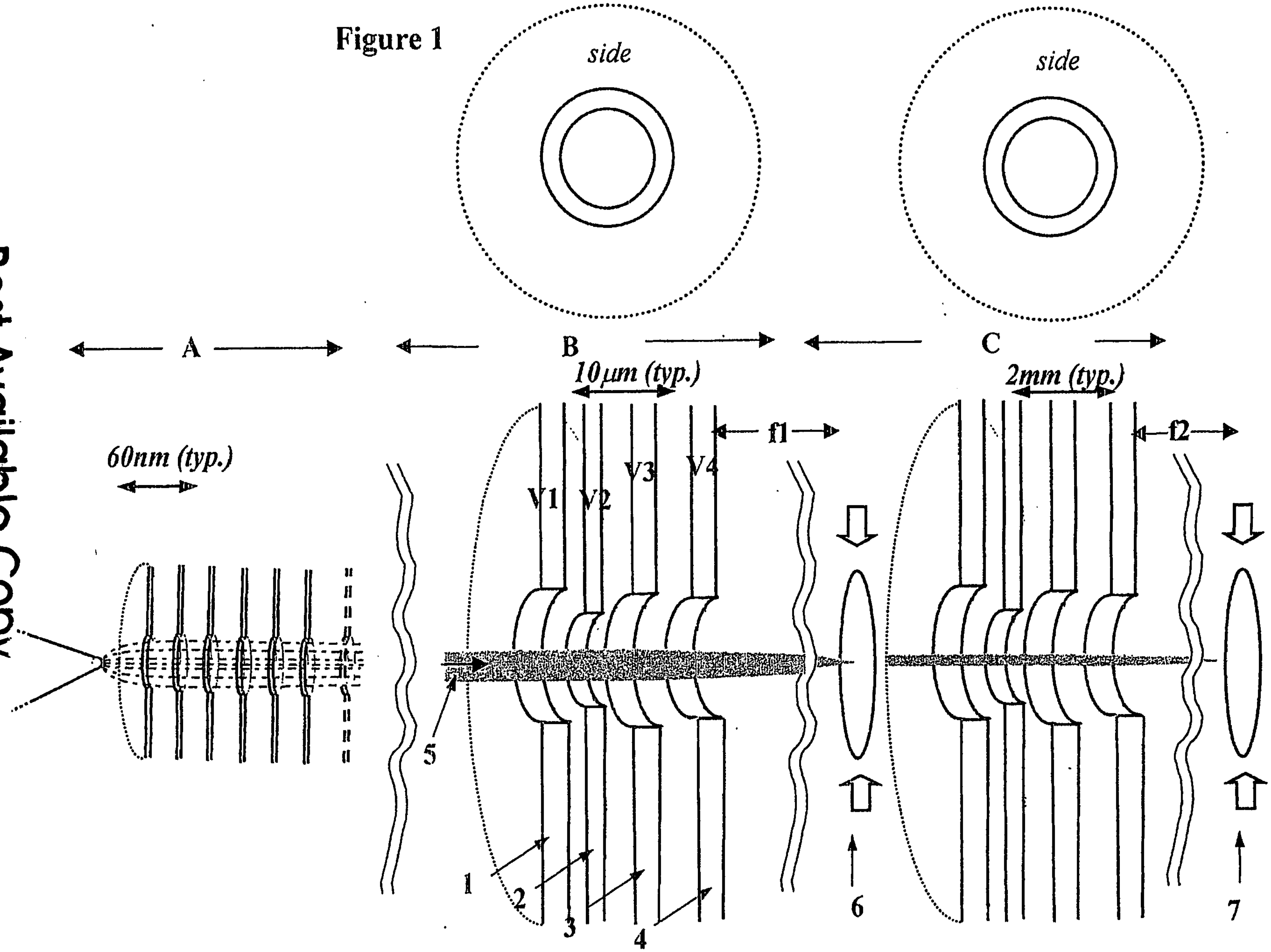
Figure 1



side
side
A
B
C
10µm (typ.)
2mm (typ.)
60nm (typ.)
f1
f2
V1
V2
V3
V4
1
2
3
4
5
6
7

Abstract

Focussed Electron and Ion Beams Addendum

A method of optimising the resolution of a new type of low-energy scanning electron microscope is described. This is to use multi-element electrostatic einzel lenses following the nanoscale field emission electron/ion source. Two lenses are used, a microscale cylindrical lens following immediately after the source and a miniature cylindrical lens further downstream from the microscale lens.

Focussed Electron and Ion Beams Addendum

In a previous application (Application number 0213772.7) we described a novel system for producing and focussing electron and ion beams (in vacuum) to extremely small lateral sizes for use in nanotechnology and high resolution scanning microscopy. The important aspects of this invention were twofold.

Firstly the source of electrons/ions was a nanotip followed by an apertured extractor plate and then an accelerating column. Because the nanotip can be positioned at nanometre distances from the nanosized circular aperture only low voltages are required to make the electric fields at the tip large enough to produce electrons or ions. (In the latter case it is necessary to supply the tip with a liquid metal such as gallium.) The accelerating section follows directly after the nanosized extracting aperture (typically 30nm diameter) and one form of this section is a stack of plates with nanoscale apertures in them. These are insulated from each other and have appropriate low voltages on them. If these voltages are correctly adjusted it is possible for the electric field on the accelerating side of the aperture to both focus and accelerate the beam of electron/ions away from the nanotip source. The brightness of this beam is calculated to exceed most, if not all, other sources on the market. A narrow, almost parallel beam with a diameter of only 30nm can be produced.

Secondly the beam from the source-accelerator can be focussed down to atomic sizes using a microscale electrostatic einzel lens with a focal length of several microns. The most important reason why this can be achieved is because of the scale invariance of the electron/ion trajectories in electric and magnetic fields. The absolute size of the focussed beam is related to the overall size of the lenses (focal lengths). Also, because the beam through this lens has a very small lateral extent the aberrations are minimal. The focussed beam after this einzel lens can then be used for microscopy if the sample is mounted on a scanning piezo arrangement at the focal point of the microscale lens. The whole assemble can be thought of as a scanning probe which uses a focussed electron beam rather than a metal nanotip. Because this is a hybrid instrument with a conventional scanning electron microscope and an STM as parents we call this instrument a scanning hybrid electron microscope or SHEM. A further miniature einzel lens can be added to the system to refocus the beam at millimetre distances from the end of the instrument. Such an

arrangement allows more space for detecting scattered electrons and for the inclusion of an electron spectrometer to measure the inelastic electron component.

This focussed beam system was described in the previous application. However we would like to make sure that these generic designs **include variations which employ the use of more sophisticated einzel lens assemblies**. To that end we show the complete system in fig. 1 which shows two four-element, cylindrical, einzel lenses, one microscale, labelled, B, and one miniature, labelled, C. These lenses are situated downstream of the electron/ion source labelled, A. Designs for aberration free multi-element lenses exist in the literature (refs. 1 and 2) but the important point about these lenses is that by having many variables in their geometry they can be made to have very low aberrations. This is somewhat analogous to multi-element optical lenses in cameras and optical instruments. The final design for these beam elements depends on the electron/beam energy, divergence and size as it enters the lens. The parameters which can be varied are:

1) The number of elements
2) The thickness of each electrode
3) The spacing between the electrodes
4) The aperture sizes in each electrode
5) The shape of the edges on the lenses as shown in the previous application
6) The voltages applied to each electrode

We have been able, by suitable variations in these parameters to almost completely eliminate spherical aberration from our system.

The figure 1 shows the geometry of the four-element lens with electrodes labelled 1,2,3 and 4 with voltages V1, V2, V3, and V4 respectively. The beam and it direction are labelled 5. A first analysis position, 6, is a focus distance, f1, from the end of the microscale lens. Scanning of the beam is achieved by moving the sample using piezos as is usual in scanning tunnelling microscopy. This sample position can be removed and the beam made to travel through the second miniature lens so as to come to a focus at a distance, f2, from the end of the second lens. At this point there is a piezo driven sample holder, 7. Although this second miniature lens is shown as having the same geometry as the first lens this need not necessarily be the case. Again the exact geometry (aperture sizes etc.) will depend on the beam properties as it passes through this lens. Typical

aperture sizes are around 5μm for the microscale lens and 5mm for the miniature lens but these can be varied over a wide range.

References

1. Setsuo Nomura, J. Vac. Sc. Technol. **B16** (1998) 104
2. Kenichi Saito et al. J. Vac. Sc. Technol. **A4** (1986) 226

Claims

1. A novel focussed electron/ion beam instrument for nanotechnology or microscopy which employs a nanoscale/microscale source using an apertured extractor electrode followed by an accelerating section. The aperture sizes in these two elements range from 10nm to 100μm. This source is designed to produce a narrow beam of electrons in the energy range from 10eV to 10keV but is most suited to operation around 300eV. The variations on this design are detailed in the previous application. (Application number 0213772.7).
2. A system in which the above is coupled to one or more multi-element, cylindrical einzel lenses which are used to focus the beam to very small lateral sizes. The multi-element lenses can be either microscale (μms) or miniature (mms).
3. A system of these lenses following the source where the following paramaters are varied for each lens; 1) the apertures of the metal plates which form the lens assembly, 2) the voltages on the plates, 3) the thickness of the plates, 4) the spacing between the plates, 5) the number of plates and 6) the shaping of the edge of the electrodes.
4. A design as above which includes constricting apertures along the beam axis to control the final beam size.
5. A design as above which includes steering electrodes to align the beam.
6. A design as above which scans the beam across the sample by using piezo electric manipulators attached to the target holder.
7. A design as above which scans the beam using electrostatic steering plates to scan the beam.
8. The ion source itself (extractor plate and accelerating structure) can also be used as a separate electron or ion source for incorporation into other devices especially if it includes one or more of the lenses.
9. The microscope is also ideally suited to incorporation into systems which also measure the inelastic component of the scattered electrons for analysis purposes.